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Interim Technical Report No. 1

MOBILITY OF FAST-MOVING SECOND-ORDER PYRIMIDAL DISLOCATIONS IN ZINC AT 77°K AND 296°K

Prepared Under Grant No. DA-ARO-D-31-124-73-G47
Project No. 11007-MC

for the

U. S. Army Research Office-Durham

by

Kenneth M. Jassby and Thad Vreeland, Jr.

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ABSTRACT

Slip bands were produced by compression stress pulses at 77°K and 296°K and observed by X-ray reflection topography. Viscous behavior of edge, screw, and mixed dislocations was observed at velocities in the range 10^3 cm/sec to about 8 X 10^4 cm/sec. The drag coefficient for second-order pyramidal dislocations was calculated from the measurements. The results indicate that phonon drag limits the dislocation velocity in these experiments.

EXPERIMENTAL TECHNIQUE

Single crystal specimens of zinc, in the shape of rectangular parallel-pipeds were prepared by strain-free chemical machining techniques. The zinc specimens were loaded on the $(1\bar{2}10)$ faces, and slip bands are observed by Berg-Barrett X-ray topography on (0001) and $(10\bar{1}0)$ crystal faces. The maximum resolved shear stress on the second-order pyramidal system occurs on $(1\bar{2}12)$ and $(\bar{1}2\bar{1}2)$ planes. Pure screw dislocations on these planes are observed on the (0001) faces, and pure edge dislocations are observed on the $(10\bar{1}0)$ faces. The four remaining second-order pyramidal planes (i.e. $(11\bar{2}2)$, $(\bar{1}\bar{1}22)$, and $(2\bar{1}\bar{1}2)$, $(\bar{2}112)$ planes) have a resolved shear stress equal to one quarter of that on the $(1\bar{2}12)$ and $(\bar{1}2\bar{1}2)$ planes. Mixed dislocations on the planes with the lower resolved stress are observed on both (0001) and $(10\bar{1}0)$ faces.

RESULTS TO PRESENT

The mobility of second-order pyramidal dislocations of edge and screw character have been measured at both room temperature and 77°K. In addition, the mobility of pyramidal dislocations of approximately 45° mixed character have been measured at 77°K.

The screw dislocation mobility results of this study are compared to those obtained by Gektina and Lavrentev[1] in Table I. The drag coefficient values of this investigation were calculated from the relation:

$$B = \frac{\tau b}{v} = \frac{I b}{d}$$

where τ = resolved shear stress

b = 5.65×10^{-8} cm

v = dislocation velocity

I = resolved shear stress impulse

d = maximum dislocation displacement

Excellent agreement is seen in Table I for the results at 296°K, and the results of this investigation at 77°K indicate a lower mobility. Screw dislocations exhibit a higher mobility than edge dislocations as is also observed on the basal slip system of zinc.[2]

From the data accumulated to this date, two points are obvious. First, dislocation mobility is seen to increase with decreasing temperature, as expected if the major contribution to dislocation damping in the region 77°K - 296°K is due to a phonon process. Second, at 77°K the dislocations of mixed character on slip planes with the lower resolved shear stress are almost four times as mobile as those of screw character on the slip planes

with the higher resolved shear stress. This large difference cannot be explained simply on the basis of their interaction with lattice vibrations (phonons). The slip bands on the higher resolved slip planes were examined in depth below the $(10\bar{1}0)$ faces and it was found that mixed dislocations on these planes did not exhibit the high mobility observed on the slip planes with the lower resolved shear stress. A tentative explanation for the large difference in mobilities is offered in the following. The pyramidal dislocations do not lie in close-packed planes and hence large atomic movements are required as a dislocation of this family moves from one atomic position to another. These movements require significant displacement normal to the glide plane of the dislocations, and energy must therefore be radiated away from the dislocation core as normal atomic displacements are effected against the compressional stresses. Now the magnitude of the compressional stresses in the case of the screw dislocations is four times that of the highly mobile mixed dislocations, and correspondingly energy dissipation can be expected to be greater in the former case.

SUMMARY AND PLAN FOR FUTURE WORK

If the above explanation is correct, then we have provided for the first time direct experimental evidence of the importance of normal forces on high-velocity dislocations and hence on plastic deformation rates. This observation suggests that the large compressive stresses on slip planes which are activated by shock waves may significantly reduce dislocation mobility.

The range of the measurements is to be considerably expanded by further tests. A new crystal growth system is being developed for the production of the highly perfect crystal required for this work.

The details of the normal stress damping mechanism are to be investigated. It is hoped to present a quantitative formulation of this problem which will be compared with experimental results.

TABLE I

DRAG COEFFICIENT FOR SECOND-ORDER PYRAMIDAL DISLOCATIONS

Orientation	Drag Coefficient, 10^{-3} dyn sec cm^{-2}			
	This Investigation		Gektina and Lavrentev[1]	
	$77^{o}K$	$296^{o}K$	$77^{o}K$	$296^{o}K$
Edge	1.1	2.2	-	-
Screw	0.75	1.1	0.48	1.0
Mixed*	0.2	-	-	-

*Compressive stress on slip plane decreased by a factor of four.

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2. D. P. Pope and T. Vreeland, Jr., Phil. Mag. 20, (1969), 1163.